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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Research is conducted toward development of high payload-fraction surface craft capable of efficient high-speed (50+ knots) coastal/short sea transport of passengers and cargo; other desired characteristics included shallow draft, steadiness, ease of reconfiguration, shock resistance and survivability in high threat areas. An experimental 42 ft lwl (50 ft oa) air-cushioned, composites constructed, catamaran is designed, built and tested to serve as a demonstrator and test bed for proprietary technology that could deliver the desired capabilities. The research vessel exhibits 25% to 50% lower hull resistance than comparable conventional fast craft, and moderate scaleups of the research vessel are estimated to be capable of full load speeds in excess of 50 kts. The craft handles and maneuvers well and exhibits very limited vertical accelerations in tested conditions up to sea state 4. Impressive fuel economy and payload capacity are projected for various scaleups (up to 125 ft length oa) of the test vessel, including very long range patrol/rescue/fireboat and 250 and 500 nm freighters, lighters and transports. Scaleups are favorably compared to Stiletto and LCAC.

15. SUBJECT TERMS

AIR-CUSHIONED, CATAMARAN, LOW VERTICAL ACCELERATIONS, LOW RESISTANCE, HIGH-SPEED, HIGH PAYLOAD FRACTION, FUEL EFFICIENCY, SHALLOW DRAFT, PATROL BOAT, RESCUE BOAT, FIREBOAT, SHORT SEAS, FREIGHTER, LIGHTER, FAST FERRY, TRANSPORT, LIGHT WEIGHT COMPOSITES, SCALABILITY, STILETTO, LCAC

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FINAL TECHNICAL REPORT

Dated February 12, 2008

RESEARCH IN ADVANCED SURFACE EFFECT SHIPS

Agreement No. N00014-05-2-0012

Between

THE OFFICE OF NAVAL RESEARCH

and

OCEAN STATE SHIPBUILDING INC.

Submitted by Douglas C. Leonard,
CEO, Ocean State Shipbuilding Inc.
Principal Investigator

Table of Contents

A. RESEARCH PROJECT

Ocean State Shipbuilding Inc. ("OSS") is a developer of proprietary technologies for optimizing the performance of air-cushioned catamarans, i.e., catamarans where a substantial portion of the bottoms of the demi-hulls are concavities that are filled with pressurized air by dedicated fans. Effective March 8, 2006, OSS entered into the above-titled Cooperative Agreement to conduct research in support of the development of high cargo-fraction surface craft capable of efficient high-speed (50+ kts) coastal/short seas transport of passengers and cargo. Other desired operational characteristics included shallow draft, steadiness in expected sea states, ease of reconfiguration, resistance to shock damage and survivability in high threat areas.

In furtherance of the stated research goals, OSS undertook to design, construct and test the largest air-cushioned catamaran that available funding would support to serve as a demonstrator and test bed for an embodiment of OSS's technology that could deliver the desired combination of vessel capabilities. Key subcontractors included SDK Structures LLC, to provide naval architecture and marine engineering services, and New England Boatworks ("NEB"), to construct the craft at its Portsmouth, RI boatyard under overall OSS direction and supervision.

The largest craft that could be constructed within budget was approximately 42 ft lwl (50 ft oa), and planning proceeded on this basis. Design work had advanced sufficiently to permit commencement of fabrication activities in July 2006, and work proceeded within budget and on schedule through completion of Builder's Trials in late April 2007. The OSS team then conducted operational testing of the vessel until early Fall 2007, generating data and investigator conclusions that are summarized in this report.

B. TECHNOLOGY DEMONSTRATOR

1. Design

The principal as-built design characteristics of the test vessel, christened *WarpDrive 1.0,* may be summarized as follows:

Scantlings and topsides		e-glass/Core-Cell® foam
Length (o.a.)		50.0 ft
Length (demi-hulls)		44.5 ft
Length (lwl)		41.7 ft
Beam (oa)		17.4 ft
Beam (demi-hulls)		6.6 ft
Hull Draft[1]:	off-cushion, full load @ rest	2 ft 3 in
	on-cushion, light ship w/ fuel @ 42 kts	1 ft 3 in
Displacement: Light ship		30,000 lbs

[1] Add c. 1 ft for surface-piercing props.

	Light ship plus maximum fuel (895 gal)	36,355 lbs
	Designed full load[2]	50,000 lbs
Motive Diesels:	(2) Yanmar 8SY-STP (2300 rpm)	2 x 900 hp
Reduction Gearing:	(2) ZF 500A, 1:1.767	
Out Drives:	(2) Arneson ASD12	
Propellers:	(2) 5-bladed, surface piercing, 32.7" diam, 50.0" pitch	
Fan Diesels:	(2) Yanmar 4JH3-THE (3800 rpm)	2 x 100 hp
Fans:	(2) 27.457" static pressure	

Standard commercial grade e-glass composites were utilized for boat structures, although utilization of more expensive e-glass and core materials would have considerably lightened the craft. *WarpDrive 1.0* was designed so that she could be outfitted with minimal additional modifications as a 49 passenger (PAX) fast ferry. Scantlings were designed to applicable requirements of the 2005 Det Norske Veritas Rules for Classification of High Speed, Light Craft and Naval Surface Craft and were approved by the U.S. Coast Guard Marine Safety Center, Washington, DC for operation under the following conditions:

Significant Wave Height (ft)	Maximum Speed (kts)
0.0 – 1.0	50
1.0 – 1.5	45
1.5 – 2.5	40
2.5 – 3.5	35
3.5 – 5.5	30
5.5 – 8.0	25
8.0 – 13.5	20
13.5 – 25.0	15
25.0 or greater	Seek Shelter at slow speed

Illustrations Nos. 1 and 2 depict the general arrangements of *WarpDrive 1.0* as built, and as designed for modification as a 49 PAX fast ferry.

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[2] The vessel has been operated at 53,000+ lbs without noticeable impairment of handling and stability. Maximum safe displacement has not been determined.

ILLUSTRATION NO. 1 - WARPDRIVE 1.0 AS BUILT

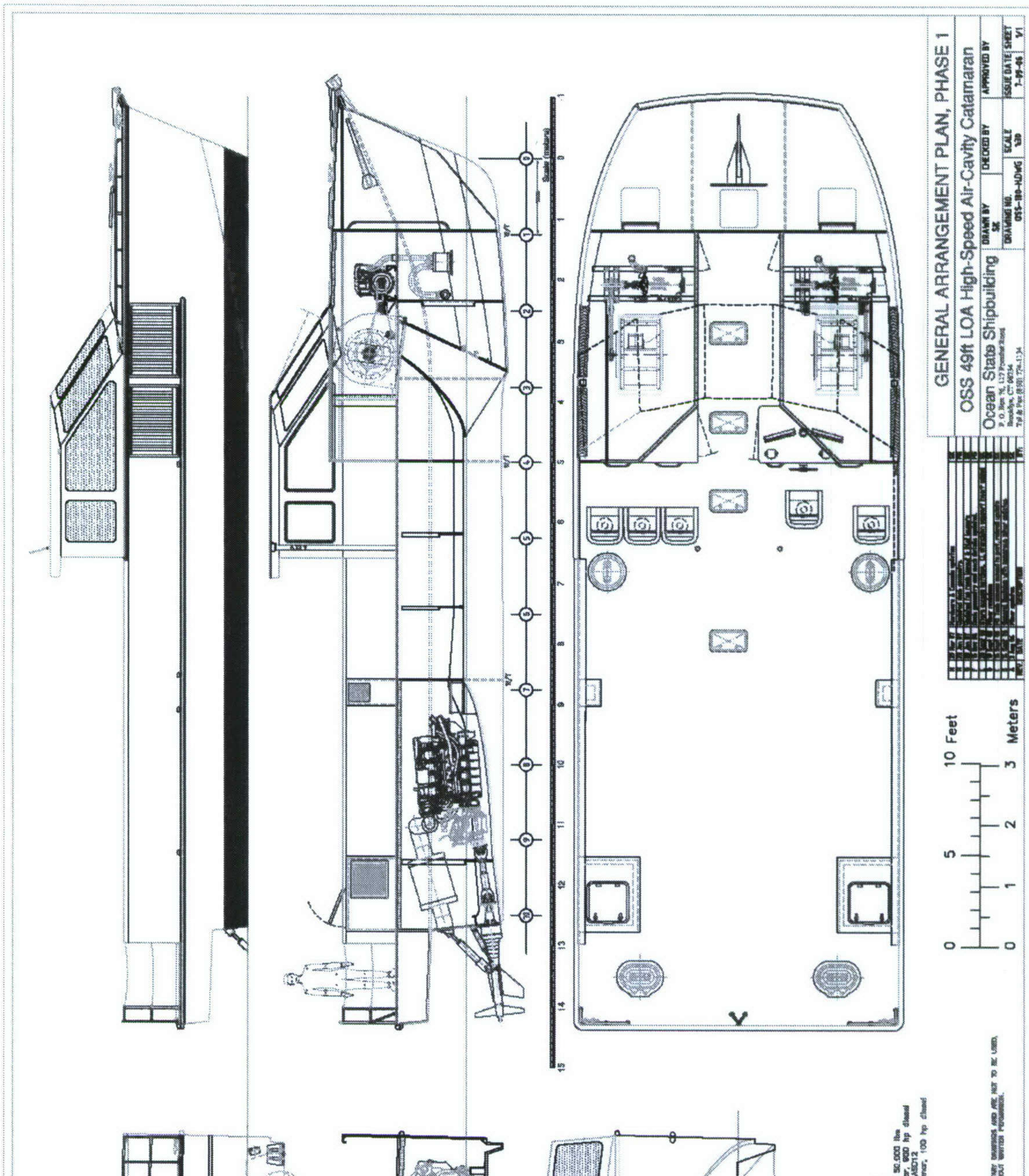
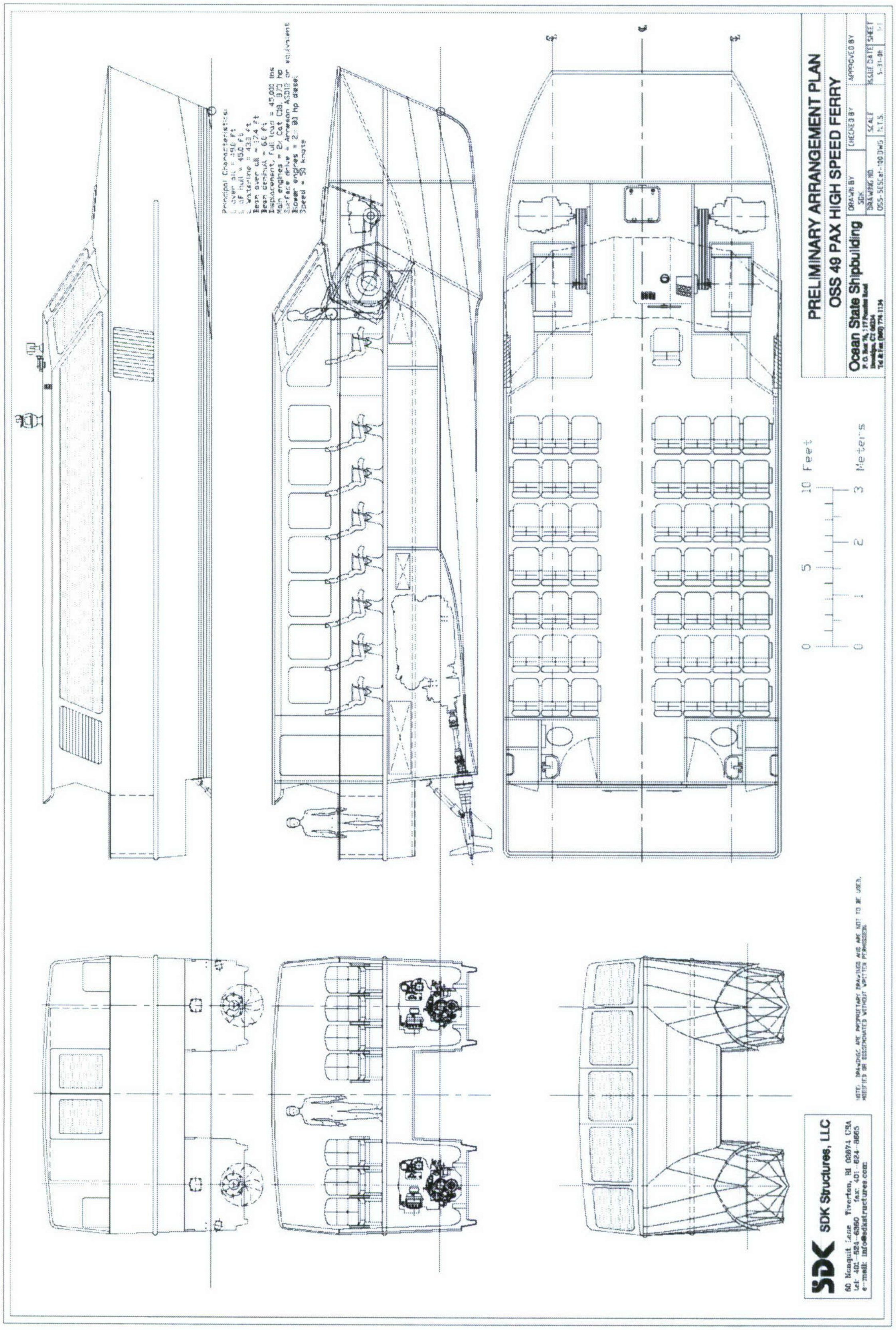


ILLUSTRATION NO. 2 – WARPDRIVE 1.0 ASSUMING COMPLETED AS FAST FERRY



2. Trials Performance

In General. Between layups at NEB for modifications and repairs, the vessel was operated on a dozen occasions from late April through early November 2007 when it was docked for the winter season. Trials were conducted in the greater Narragansett Bay area, typically in light conditions although the vessel was also operated in conditions up to sea state 4. Through the use of flexible bladders that could be placed in various locations on the main deck and filled with sea water, the vessel was operated at various trims and displacements ranging from c. 33,500 to 53,000 lbs. Generally, the vessel's performance met or exceeded expectations, handling well in all tested conditions and proving to have significantly less hull resistance than conventional high speed craft (see "Hull Resistance", below).

Ride. The boat displayed a remarkable lack of significant vertical accelerations at all speeds and in all tested conditions, including passage in 3-4 foot seas at 30-35 kts and in 4-6 foot seas with waves breaking over the cabin at 25-30 kts. The exceptionally smooth ride, particularly at full load, is posited to be due in large part to the inherent shock-absorbing qualities of the air cushions.

Handling. The boat proved to be very responsive in all tested conditions to helm and throttle. The boat accelerated easily and executed turns at 40 kts within a tactical diameter of c. 100 ft. The boat was noticeably steady in all tested conditions, heeling moderately in turns and being relatively insensitive to wave conditions. A particular surprise was the ability of the boat, even at full speed, to stop within about a boat's length by throttling down both the main propulsion and fan engines.

Trim. The boat's performance did not seem to be particularly sensitive to trim, although handling and speed were both enhanced by assuring that the boat did not excessively trim by the stern, particularly when approaching "hump" speed. Once the boat achieves planing speed, the stern rises rapidly and she is felt to literally stand up. Being a broad catamaran, the boat also is relatively insensitive to beam seas and laterally unequal deck loading. For instance, on one occasion when the port fan engine had quit and the boat was additionally carrying a couple of thousand lbs of unbalanced ballast on the port side, the boat cruised at 22 kts with the starboard fan operating at full power with no significant list to port and or degradation of handling.

Dynamic Stability. Disturbingly, but fortunately only at speeds in excess of 35 kts and only at light displacement, the craft tends to list, preferentially to starboard, causing difficulties in steering and maintaining speed. After the addition of spray strips the list occurred less often, was less severe, and typically was easily correctable or preventable by compensating use of trim tabs without noticeable loss of speed.

Speed.

Fans & Planing. The boat will not plane and is limited to, at most, about 19 kts without fans power, even at lighter displacements. No systematic measurements were made to determine the minimum speed at which application of fan power enabled planing. However, on the emergency occasion (see above) when the boat was operated on only one fan, the boat was at full load and would not make more than about 6.5 kts until the starboard fan was started up, at which time the boat rapidly accelerated to 21-22 kts. More typically, the fans would be engaged at about 8 or 9 kts to enable rapid planing and a pronounced forward acceleration, typically reaching 25 kts in a matter of a few seconds and continuing to smoothly accelerate until the engines were maxed out.

Maximum Speed. Most disappointing was the failure of the boat to make maximum speeds approaching those claimed to be achievable by other proponents of air-cushion catamarans. Maximum trials speeds ranged from 46 kts at 37,500 lbs to 38 kts at 49,600 lbs. The size of the speed shortfalls was sufficient to argue persuasively that hull drag is significantly greater than anticipated. However, the inability of the propulsive diesels to operate at greater than 2050-2100 rpm (compared to a rating of 2300 rpm), when the props were set at efficient depth, indicates that a substantial portion of the maximum trials speed shortfall is attributable to the propellers being designed for a vessel with lower hull resistance, thereby exerting an undue load on the engines causing their computerized control heads to limit rpms. As a consequence, propeller efficiency at full load is estimated by the propeller supplier to have been only about 54% vs. a designed 68-70% level.

Alternative Propellers. By more closely matching propeller design to hull resistance (by decreasing propeller "cup", pitch and/or diameter), propeller efficiency should be restorable to design level, and the vessel should be able to achieve appreciably higher speeds (see "Maximum Speed", below). Unfortunately, there were not sufficient funds to acquire, install and test alternative propellers in the course of this research project. All projected performance data for WarpDrive 1.0 and scaleups in the remainder of this report assume properly matched propellers.

3. Hull Resistance

Trials data indicate that the *WarpDrive 1.0* hull type, despite the disappointing trials speeds, is markedly more efficient than conventional high-speed vessel alternatives. Table No. 1 lists the trial speeds obtained at various displacements and rpms, as well as propeller EHP calculated on the assumption that EHP varies by the cube of shaft rpm. The table also includes the corresponding Froude numbers and, based upon the estimated EHP, the hull resistance-to-weight ratio (R/W) for each measurement by applying the following formulae (the "Fundamental Formulae":

Froude No. = 0.298 x V / L,

(where V = speed in kts, and L = the square root of the load water line), and

R/W = 329 x E / V / W

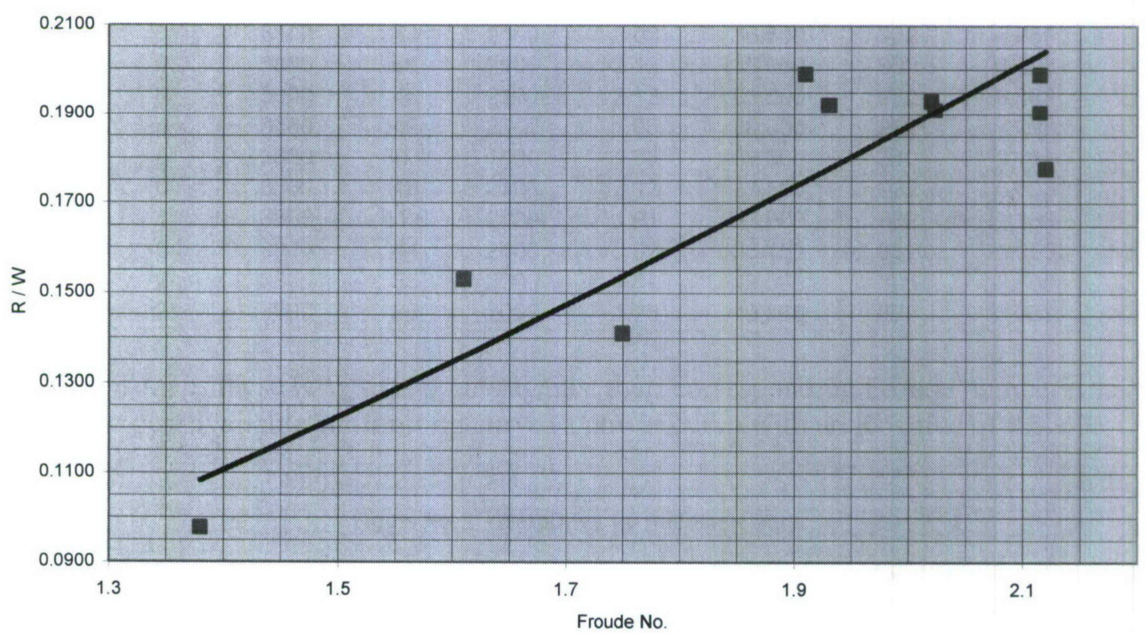
(where V = speed in kts, E = propeller EHP, and W = displacement in lbs)

TABLE NO. 1 – TRIALS DATA, FROUDE NO. AND HULL RESISTANCE

	Wave Hgt (ft)	Fan Engs. RPM	Kts	Main Engs. RPM	Froude #	W (Lb Displ)	Prop HP	R *	R/W
April 24	0	3800	42	2100	1.93	38,000	932	7,298	0.192
April 26	0	3800	44	2100	2.02	36,500	932	6,966	0.191
May 1	0	3800	46	2100	2.12	35,000	932	6,663	0.190
May 3	0	3800	46	2100	2.12	33,500	932	6,663	0.199
June 29	0	3800	42	2100	1.93	38,000	932	7,298	0.192
June 29	0	3800	30.1	1500	1.38	38,000	340	3,711	0.098
July 6	0	3800	46	2100	2.12	37,500	932	6,663	0.178
Sept. 22	1	3800	41.6	2100	1.91	37,000	932	7,368	0.199
Oct. 19	0	3800	44	2100	2.02	36,153	932	6,966	0.193
Nov. 7	2	3800	35	2000	1.61	49,566	805	7,565	0.153
Nov. 7	2	3800	38	2000	1.75	49,566	805	6,968	0.141

Figure No. 1 maps these R/W data points against their corresponding Froude numbers and displays the best available conforming curve (a power curve with an R^2 value of 0.8213).

Figure No. 1 - WarpDrive 1.0 Hull Resistance



As shown by Figure No. 2, *WarpDrive 1.0*'s resistance curve closely tracks the resistance curve derived from the powering data recorded by SSPA Sweden AB when testing scale models of air-cushion catamarans of similar design[3].

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[3] See "An Airlifted Catamaran – Hydrodynamical Aspects", Bjorn Allenstrom, Hans Liljenberg and Ulf Tudem, "FAST 2001" International Conference: 4th – 6th September 2001, Southampton, UK, The Royal Institution of Naval Architects.

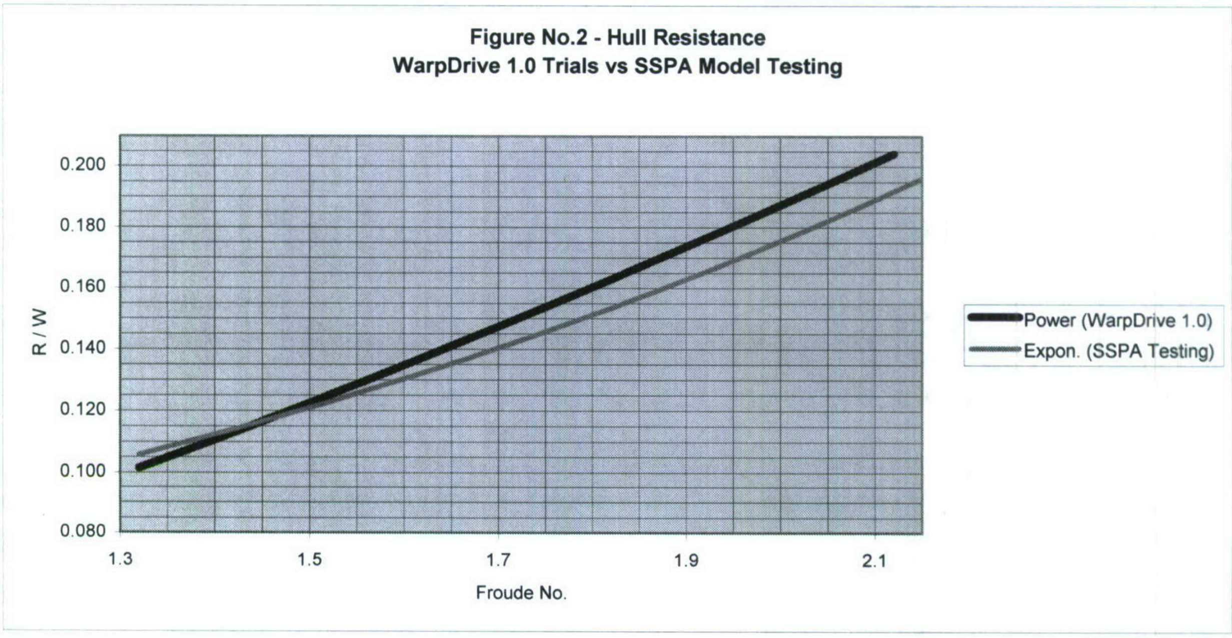
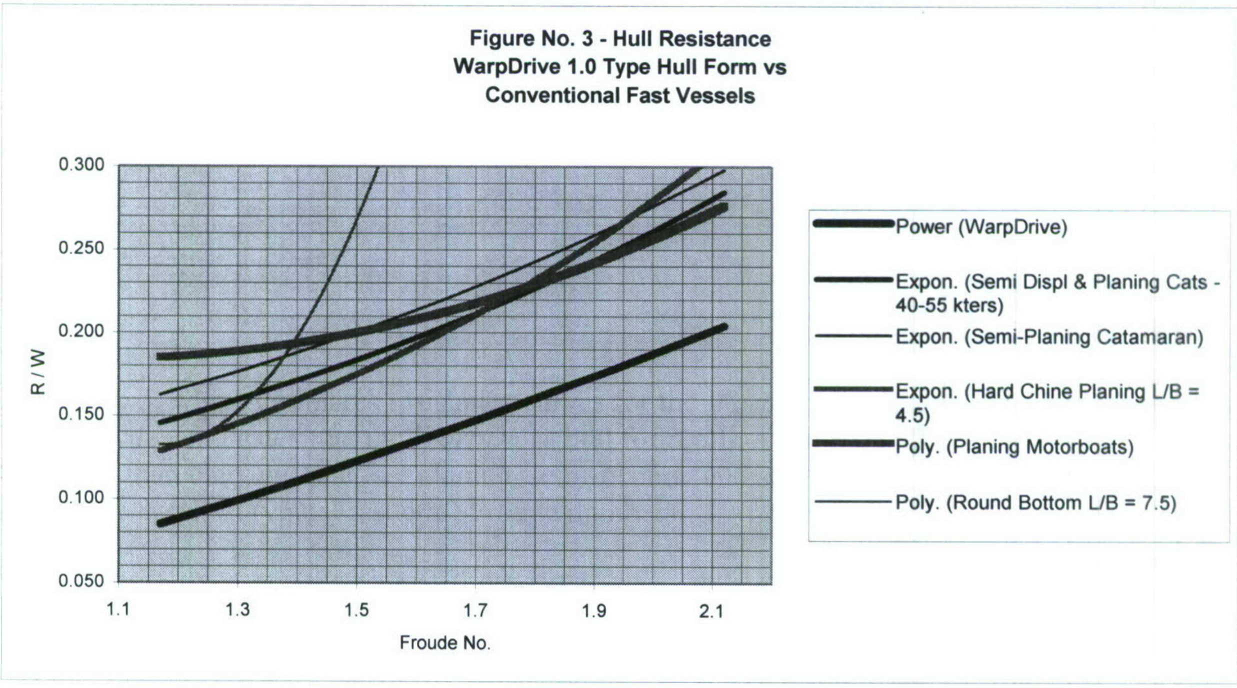


Figure No. 3, which compares resistance curves for the *WarpDrive* hull type and various other fast hull types, indicates that the *WarpDrive* hull form offers approximately 25% to 50% less resistance than conventional fast planing, semi-planing and semi-displacement catamaran and monohull vessels at typical fast craft Froude numbers[4].



[4] The curve for semi-displacement & planing catamarans is derived from the paper referenced in footnote 3. The other curves are derived from "Air-Assisted Catamaran Concepts for Amphibious Operations", Wayne Johnson and Don Burg, "Warship 2000" International Conference, Royal Institution of Naval Architects.

4. Projected Speed

Maximum speeds obtainable by *WarpDrive 1.0* may be estimated by applying the Fundamental Formulae to the WarpDrive resistance curve. Estimated maximum speed obtainable at various displacements with her current 1800 hp propulsive power plant are as follows:

35,000 lbs	50.0 kts
40,000 lbs	47.5 kts
45,000 lbs	45.2 kts
50,000 lbs	43.1 kts

C. TECHNOLOGY APPLICATION PARAMETERS

1. Scalability

Due to the relative infancy of the use of composites in the fabrication of larger craft, it is currently deemed prudent to limit scaleups of the WarpDrive hull form to about 125 ft length oa (c. 105 ft lwl), or about 2.5 times the length of the demonstrator vessel. Subject to confirmation of the performance increase to be obtained with alternative propellers, there is considerable reason to believe that the *WarpDrive 1.0* demonstrator is of sufficient size, completeness and performance to be used confidently as a template for the design and large-scale production of naval, commercial and pleasure craft of similar hull form up to this size limit. Larger sized vessels fabricated of other relatively light-weight materials (e.g., aluminum) would be possible, but would suffer in payload fraction and/or performance due to the weight penalty that would have to be paid.

Scaleups described in the remainder of this report assume strictly cubic dimensional and weight expansion of hulls and propulsion plants and, except as otherwise noted, of topside. Although detailed design work has not been commenced, in applications dominated by low weight density payloads (e.g., fast ferries) it is projected that sufficient deck space can be made available by addition of a second, partial or full deck and separate (superimposed) pilothouse.

2. Sea State

In view both of the limited size and shallow draft of the currently envisioned WarpDrive type vessel, it would appear prudent to limit operations to riverine, coastal and immediately off-shore environment. In particular, although the Coast Guard has approved the 42 ft lwl demonstrator for operations in weather with up to 25 ft significant wave height (i.e., low sea state 7), to limit passenger and crew discomfort, limited trials experience suggests that non-emergency high-speed operations be limited to seas where the average length of waves approximates the lwl length. For craft ranging from 1.0 to 2.5 times the lwl of the demonstrator, this would imply the following limiting conditions for extended high-speed operations:

Length lwl (oa)	Significant Wave Height	Sea State
42 ft (50 ft)	3.0 ft	2.5
63 ft (75 ft)	5.0 ft	3.5
84 ft (100 ft)	6.5 ft	4.0
105 ft (125 ft)	8.0 ft	5.0

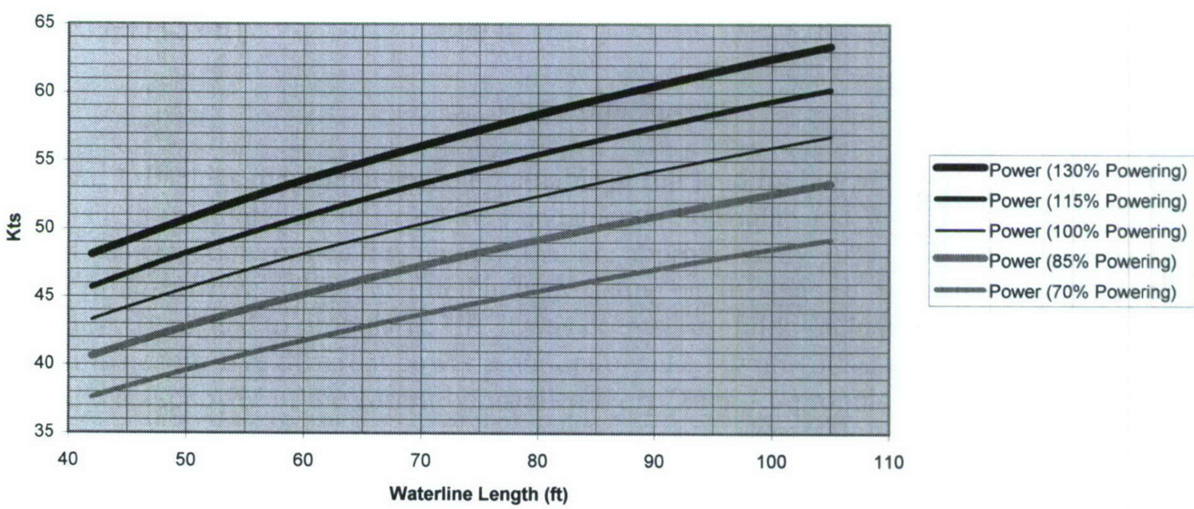
Limited trials experience also prelimarily suggests that, at commercial service speed (i.e., approx. 85-90% shp), extended operations be limited to approximately 1.25 times the lwl length, or the following approximate sea conditions:

Length lwl (oa)	Significant Wave Height	Sea State
42 ft (50 ft)	4.0 ft	3.0
63 ft (75 ft)	6.0 ft	4.0
84 ft (100 ft)	8.0 ft	5.0
105 ft (125 ft)	10.0 ft	5.0

3. Maximum Speeds

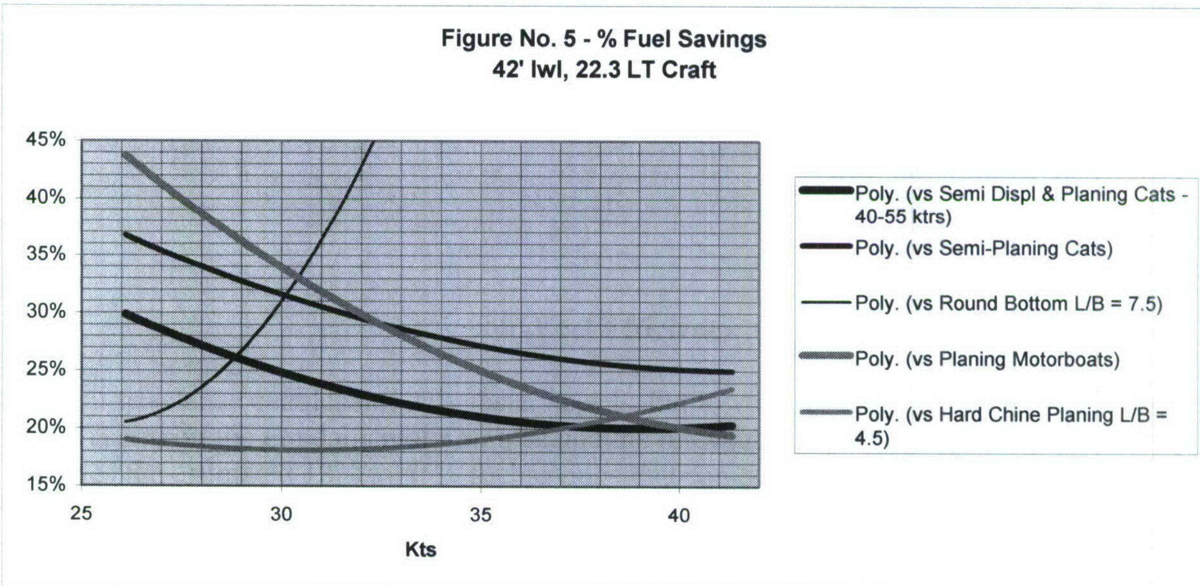
Figure No. 4 displays maximum speed obtainable at full load by *WarpDrive 1.0* and scaleups of varying length calculated by utilizing the Fundamental Formulae and WarpDrive resistance curve. It has been determined that engines that are approximately 30% more powerful than those installed in *WarpDrive 1.0* can be fitted in her existing engine spaces. Since both speed and fuel use are directly related to propulsive HP, it was deemed useful to include in the chart maximum speed estimates for five different power plant options, i.e.: with 130%, 115%, 100%, 85% and 70% of the horsepower of the currently installed *WarpDrive 1.0* propulsive plant and scaleups.

Figure No. 4 - Maximum Full Load Speed
WarpDrive 1.0 & Scaleups

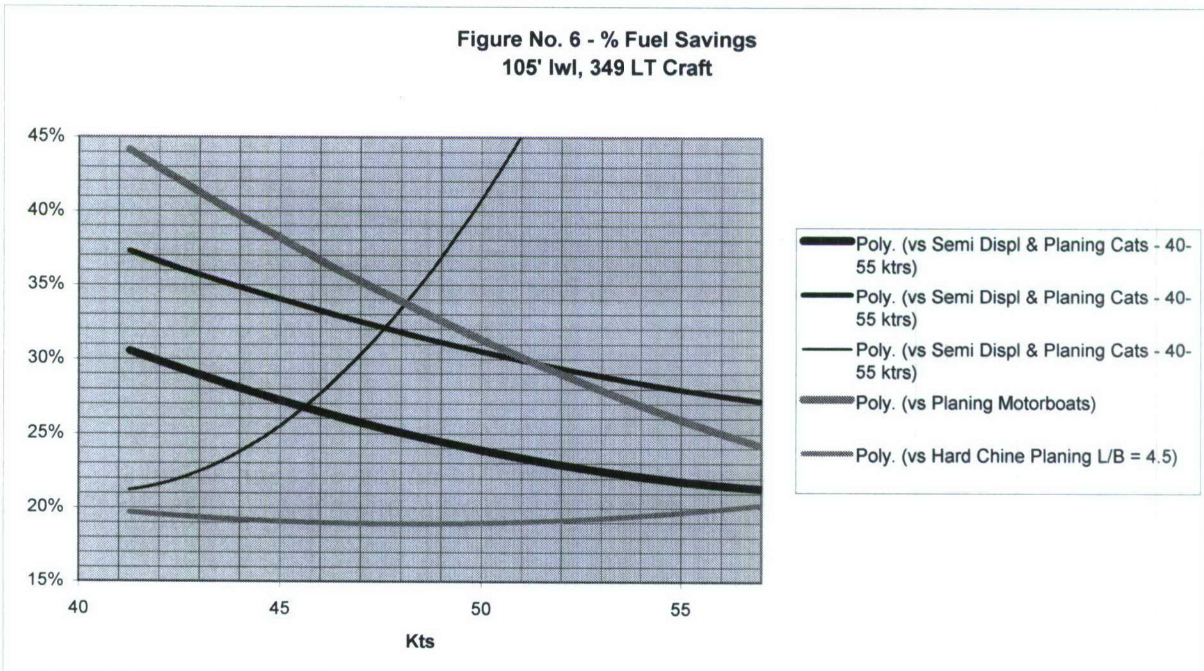


4. Fuel Efficiency

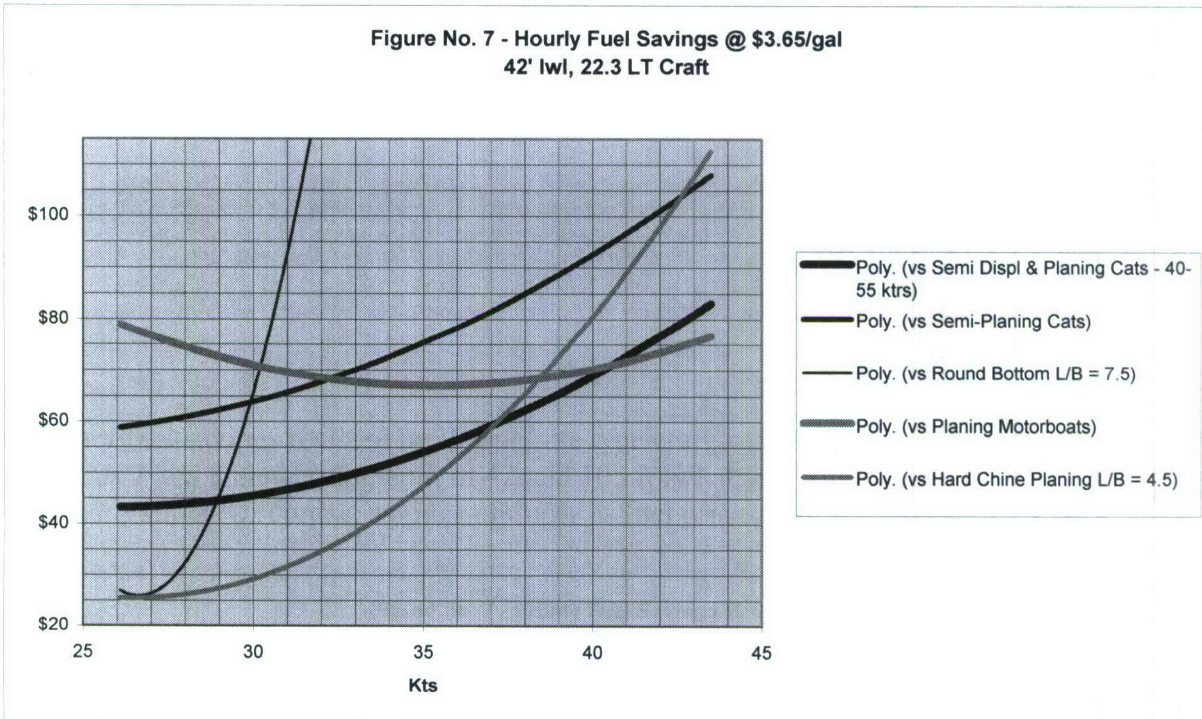
Low hull resistance enables not only faster speeds, but lower fuel consumption at any given speed. Based on the Fundamental Fomulae and the relevant resistance curves, Figure No. 5 illustrates the estimated 18% to 45% fuel savings that can be realized by utilizing a 42 ft lwl, 22.3 LT WarpDrive type craft compared to conventional fast craft of like length and tonnage.

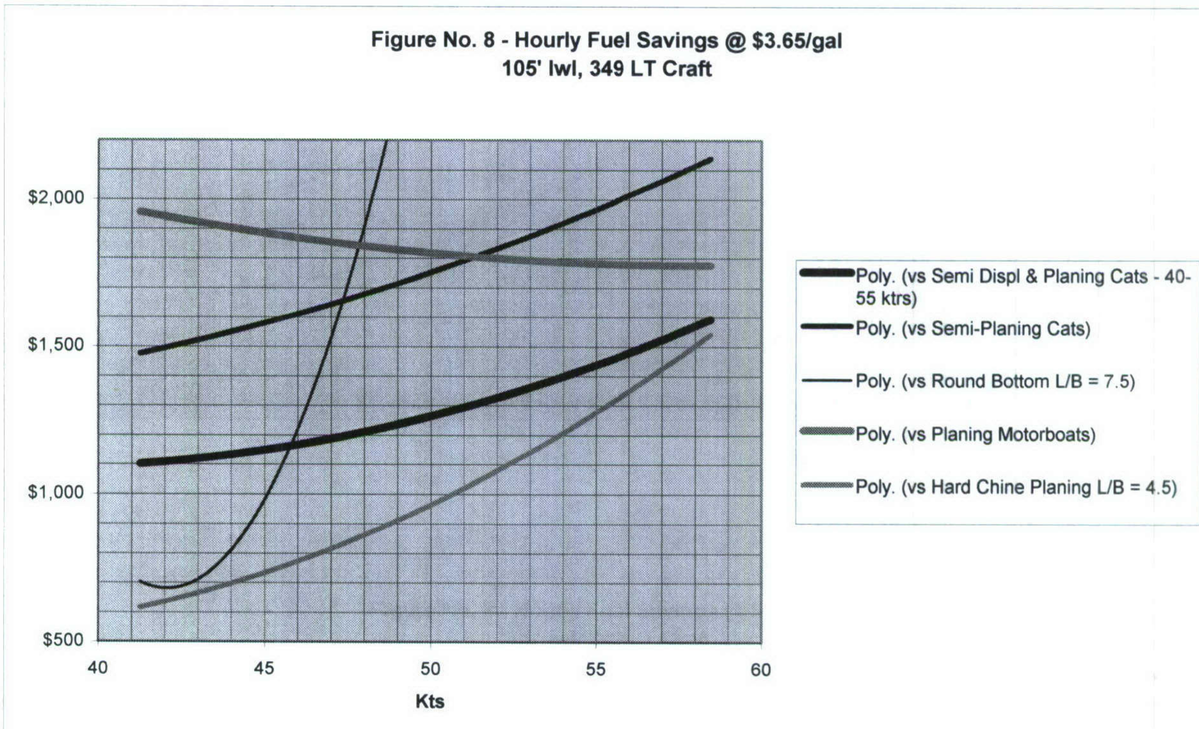


Relative % fuel savings are similar for larger craft, except at higher speeds due to the effect of waterline length on speed codified by Froude. See Figure 6 below.



Monetary fuel savings realized by WarpDrive type craft track the percentage savings, as shown in Figures 7 and 8 concerning craft of 42 and 105 ft lwl at an assumed current diesel fuel cost of $3.65 per gallon. Of course, savings multiply as fuel prices rise.





5. **Light Weight Construction**

In order to hold down material and labor construction costs, *WarpDrive 1.0*'s scantlings and topside structures were fabricated of commercial grade e-glass and core materials such as Core-Cell®, and it is contemplated that such materials will typically be used in future craft for similar reasons and, unless otherwise noted, all WarpDrive type craft described in this report would be similarly constructed. However, in certain applications where high payload fraction is at a premium, the high strength of certain materials may justify higher construction costs. For instance, at the price of approximately 100% to 300% additional acquisition cost, such high-strength, light-weight materials as carbon fiber e-glass, Nomex® and honeycomb Kevlar® could be extensively substituted in order to achieve weight reductions, where applied, of approximately 50%. It is roughly estimated that extensive use of such materials could lighten scantlings and topside structure by about 25% overall, thereby reducing total vessel weight by approximately 16%, depending upon equipment outfit.

D. PREFERRED APPLICATIONS

1. Introduction

The set of performance characteristics, coupled with size and sea state limitations, suggests certain preferred embodiments of the WarpDrive technology, all offering high speeds and limited to 125 ft length oa:

- Cruiser – Patrol, rescue, etc. cruising.
- Freighter – For short seas cargo hauling, typically for c. 500 nm at maximum speed.
- Lighter – For rapidly loading or offloading ocean-going vessels, typically for c. 250 nm at maximum speed to and from shallow, isolated and/or primitive docking facilities.
- Transport / Ferry – Fast people transport, typically for c. 500 nm at maximum speed.

Each of these preferred applications of WarpDrive technology is examined briefly below.

2. Cruisers

WarpDrive Cruisers would be designed for specialized tasks other than freight and passenger carriage and, in certain configurations, would have exceptional range for a small craft. Although larger vessels could be considered for this type, this report will only treat the 42 ft lwl version of this type of WarpDrive craft as it appears to be particularly suited to the tasks treated in this report, namely, patrol, rescue and perhaps firefighting.

Illustration No. 3 pictures a patrol and rescue Cruiser with the essentially the same hull and structural characteristics as the 42 ft lwl technology demonstrator vessel except for the partially extended cabin and enhanced amenities.

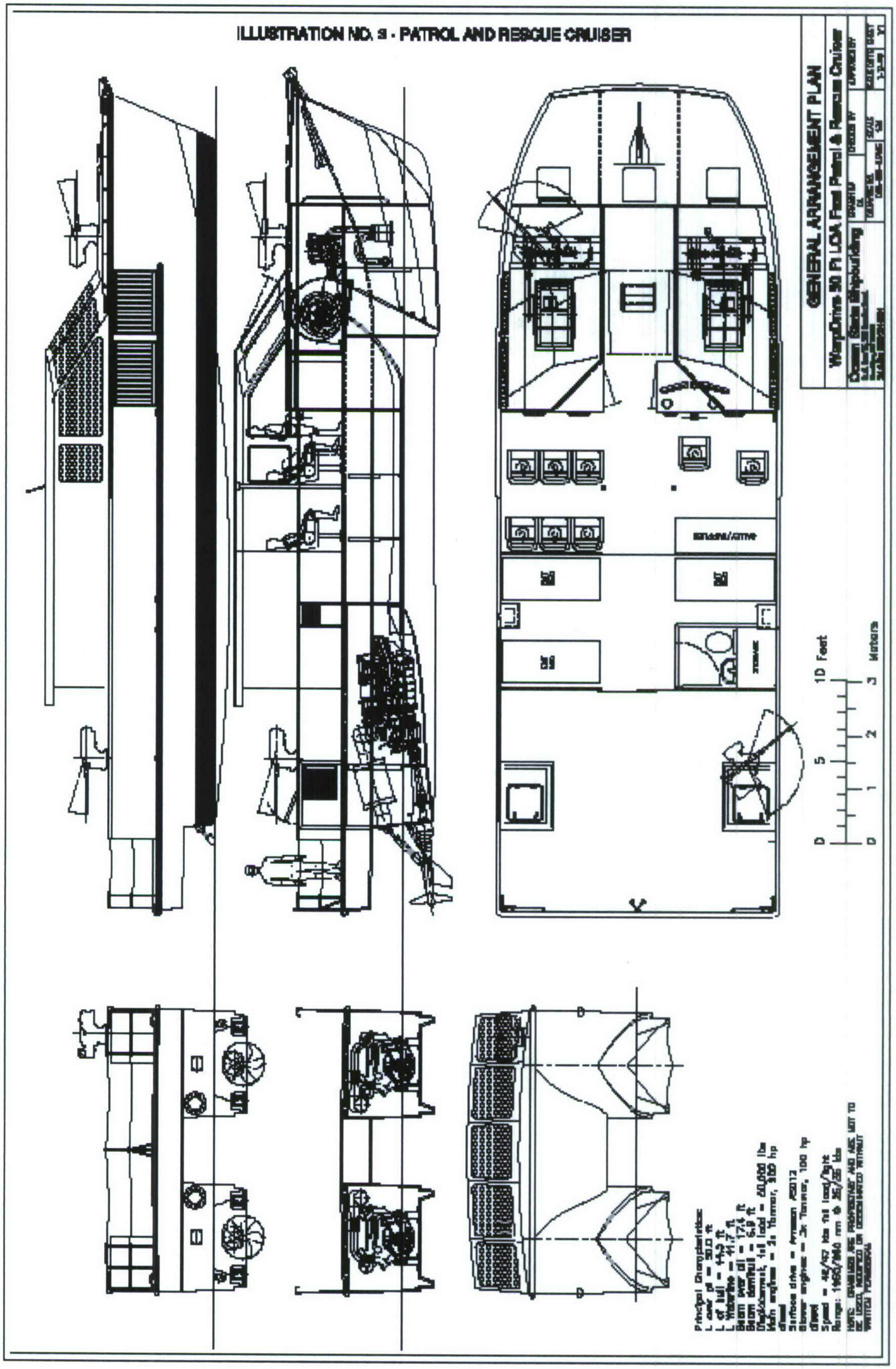


ILLUSTRATION NO. 3 - PATROL AND RESCUE CRUISER
GENERAL ARRANGEMENT PLAN
WarpDrive 50 Ft LOA Fast Patrol & Rescue Cruiser
Ocean State Shipbuilding
0 5 10 Feet
0 1 2 3 Meters
Principal Characteristics
L over all = 50.0 ft
L Waterline = 41.7 ft
Beam over all = 17.4 ft
Surface drive = Arneson ASD12
Speed = 46/47 kts full load/light

In addition to the usual safety, electronic and emergency equipment, the depicted craft would include:

- Seating for 3-man crew
- Seating for 5-man boarding party/assault unit, or rescuees
- (2) Raphael Mini-Typhoon®stabilized, CCD/ICCD/FLIR-guided, remotely operated weapon systems, each carrying a Browning .50 cal. or MPMG 7.62 mm machine gun, a 40 mm grenade launcher or a Spike LR fire-and-forget surface-to-surface missile launcher, together with Raphael's Fast Patrol Boat Combat Suite
- EMT equipment to utilize aft cabin spaces and bunks as full-service emergency room for rescuees and/or casualties
- Stowage for supplies, weapons, etc
- Optionally, approximately 4,575 lbs of armored glass and aluminum oxide composite armor to protect propulsive and fan power plant and cabin areas at NIJ Threat Level IV against ball and AP medium caliber

In light of the craft's potentially long range, multi-day endurance capability (see below), the Cruiser would also be provided with:

- (3) beds for hot bunking crew and passengers in shifts
- Full lavatory
- Galley
- Cold and room temperature storage for several days' consumable supplies

The Cruiser could be made firefighting capable by applying weight otherwise devoted to armor and/or fuel to a full firefighting equipment suite.

The unarmored and armored versions, with service displacements (i.e., full displacement less fuel load and cargo allowance) of approximately 36,765 and 41,337 lbs, respectively, are estimated to make the following speeds at full load and at their respective service displacements, depending upon the selected power plant:

	Speed (kts)		
Power Plant Option	Full Load	Armored Service Displacement	Unarmored Service Displacement
130%	48.1	52.0	54.6
115%	45.7	49.4	51.7
100%	43.3	46.8	48.9
85%	40.6	43.8	45.9
70%	37.6	40.4	42.4

If the 13,235 or 8,663 lbs of excess full load displacement, over and above the service displacement, of the unarmored or armored version is applied entirely to fuel tankage, the patrol and rescue Cruisers would have extraordinary range for craft of such size. Range (nm) is estimated to be as follows, depending upon selected power plant and cruising speed:

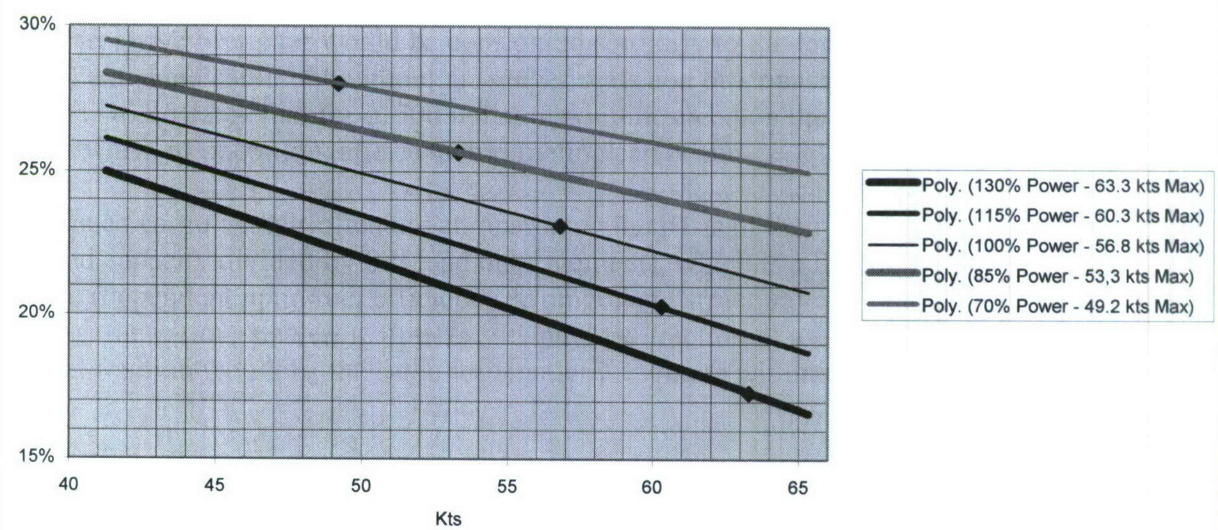
Type	Power Plant	Cruising Speed (kts) 25	30	35	40	45	50
Armored:	130%	384	352	326	305	289	275
	115%	612	561	520	487	461	439
	100%	909	834	772	723	685	652
	85%	1,311	1,202	1,114	1,043	988	941
	70%	1,886	1,728	1,601	1,499	1,421	1,353
Unarmored:	130%	775	710	658	616	584	556
	115%	1,059	971	900	842	798	760
	100%	1,429	1,310	1,214	1,137	1,077	1,025
	85%	1,930	1,769	1,639	1,535	1,455	1,385
	70%	2,646	2,425	2,247	2,104	1,994	1,898

3. Freighters

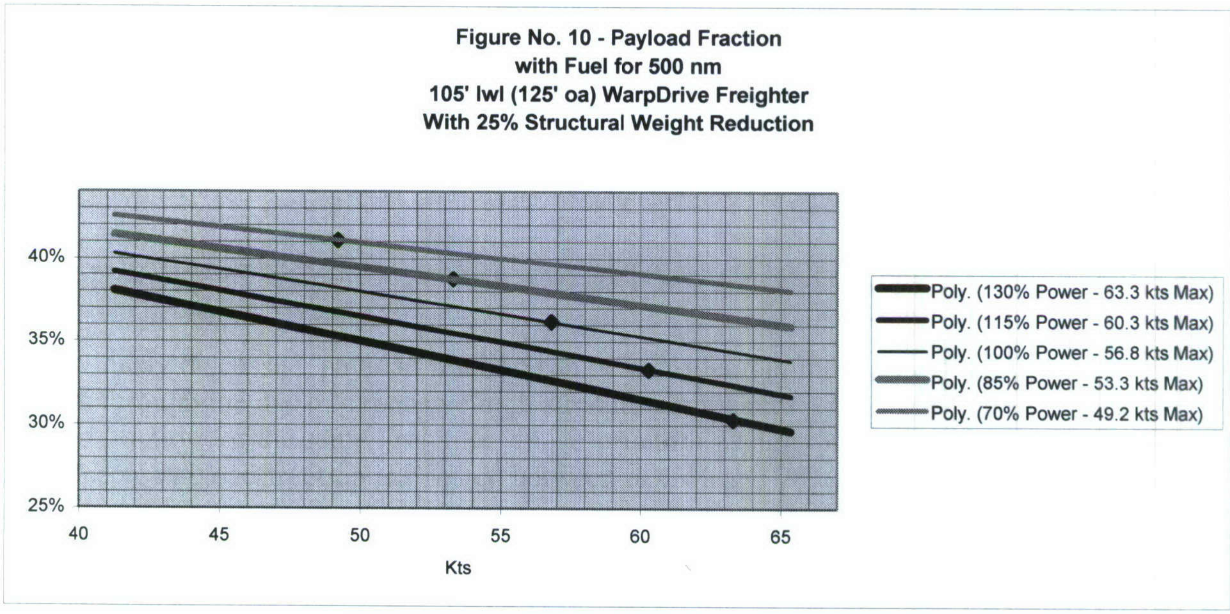
The WarpDrive Freighter would be configured similarly to the ferry version of *WarpDrive 1.0*, with an extended cabin but without passenger seats and other passenger amenities. Typically, the craft would carry fuel for c. 500 nm at maximum speed on the theory that this will constitute a day's worth of operation, after which refueling can occur.

High-speed cargo vessels often are compared on the basis of their payload (cargo) fraction (payload capacity divided by full load displacement), which is a function of vessel length, fuel tankage (dependent upon fuel efficiency & range) and structural/equipment weight. Figure No. 9 displays, for various powering options, the payload fraction of a 105 ft lwl WarpDrive Freighter. Payload fraction would be the same for smaller Freighters within their slower speed domains.

Figure No. 9 - Payload Fraction with Fuel for 500 nm 105' lwl (125' oa) WarpDrive Freighter



As previously discussed, payload fraction can be considerably increased by reducing structural weights through the use of expensive high strength composites. Figure No. 10 shows the payload fraction for the same Freighter whose structural weight has been reduced by 25%. As can be seen, payload fraction is boosted between c. 43% and 78%, depending upon operational speed.



The projected fuel cost per LT of payload per nm (for five different power plant options), at an assumed diesel price of $3.65 per gallon for 63 ft and 105 ft lwl Freighters is shown in Figures Nos.11 and 12. Of course, substantially lower fuel costs could be obtained with light-weight structural composites. Average service speed (i.e., at 90% max shp) is also shown for each power plant option. As can be seen, the cost per LT per nm is substantially less for the larger vessel at all speeds.

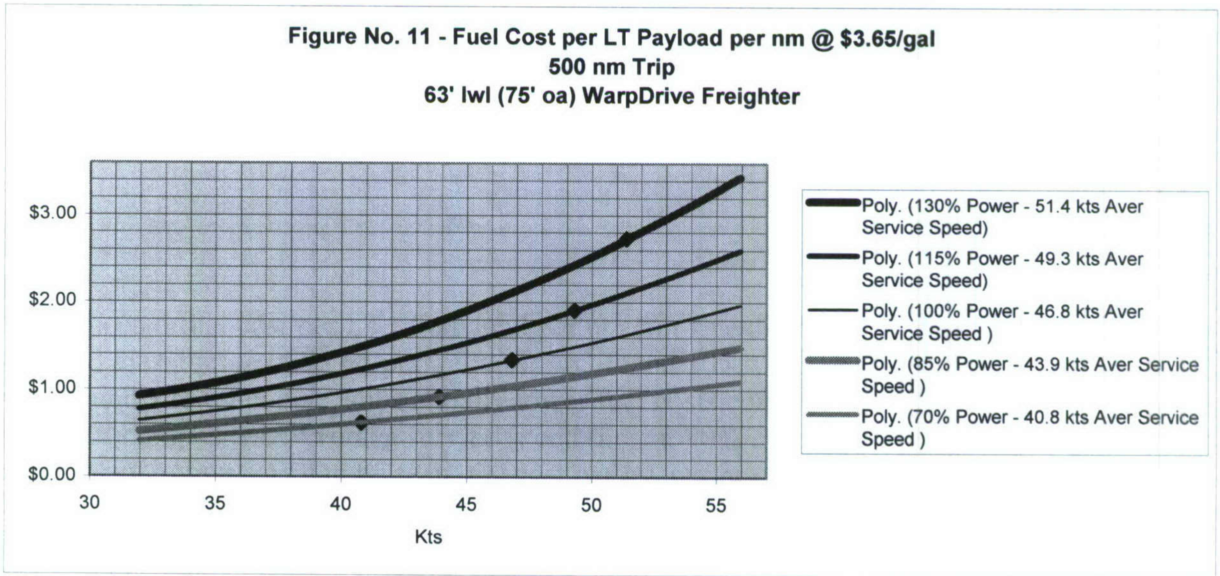
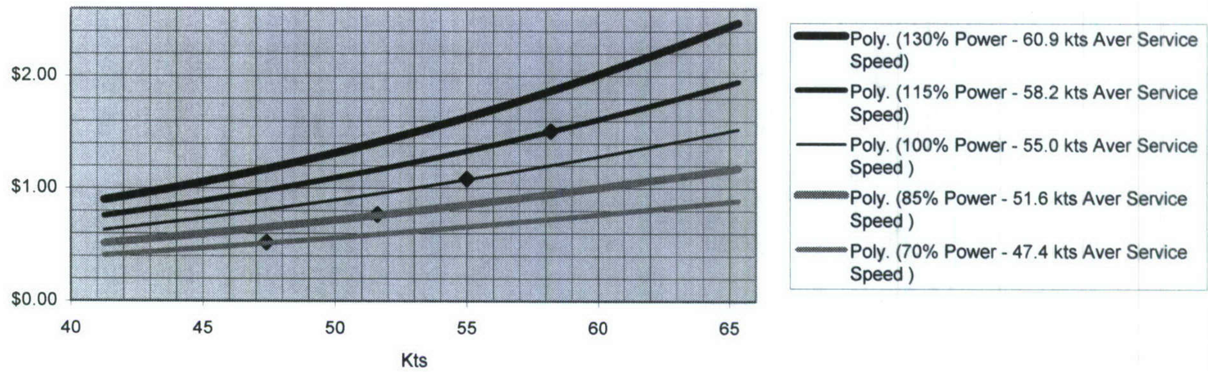


Figure No. 12 - Fuel Cost per LT Payload per nm @ $3.65/gal
500 nm Trip
105' lwl (125' oa) WarpDrive Freighter



The only U.S. Navy vessel with substantial payload fraction and range in excess of 250 nm that is claimed to make 50 kts at full load is the experimental craft Stiletto. Table No. 2 compares Stiletto with a 58.4 ft lwl WarpDrive Short Seas Freighter with 25% structural weight reductions, a 112% power plant option and fuel for 500 nm. This length was chosen to equalize the WarpDrive craft's full load displacement with the reported 60.0 LT of Stiletto. The 25% structural weight reduction was opted for since it is reported that super light composites (including carbon fiber e-glass) were extensively used in Stiletto's fabrication, and the power plant upgrade was specified in order to achieve 50 kts at full load. As can be seen, Stiletto can carry 6% more payload due to its 2.0 LT lighter standard displacement, which is partially offset by WarpDrive's smaller power plant and corresponding smaller fuel load. However, due to WarpDrive's lower power needs, she burns 3% less fuel per LT of payload per nm. Further, with a 30.5% structural weight reduction, the WarpDrive craft's payload fraction equals Stiletto's and the fuel burn rate advantage increases to 9% .

Table No. 2 - Short Seas Freighter vs Stiletto

Vessel	Stnd Displ. (LT)	Fuel (LT)	Full Load Displ. (LT)	Payload (LT)	SHP	Full Load Max Speed (kts)	Range (nm)	Payload vs Power (lbs / HP)	Payload vs Full Load Displ.	Fuel Use per Payload-Mile At 50 kts (gal / LT / nm)
Stiletto	32.2	9.5	60.0	18.2	6,600	50	500	6.2	30.4%	0.33
WarpDrive	34.2	8.7	60.0	17.1	6,009	50	500	6.4	28.5%	0.32

Notes: Stnd Displ. = Standard Displacement = fully equipped and manned, but without fuel.
All fuel tankage calculated assuming fuel usage at .045 gal / hp / hr for 500 nm.
All payloads calculated by subtracting Stnd Displ and Fuel from Full Load Displacement.
Stiletto Stnd Displ, Full Load Displ, SHP, Speed and Range data is per OFT websites.

4. Lighters

The WarpDrive Lighter is essentially a Freighter that carries less fuel due to its more pronounced loading – offloading role. For a vessel that may spend perhaps 50% of the operational day immobile at dockside, an operation range of 250 nm is not unreasonable (note, the LCAC, which essentially is a short-range personnel and equipment shuttle, reportedly has a 200 nm operational range).

As indicated above, payload fraction is sensitive to operational range because the amount of weight devoted to fuel varies directly with operational range. Figures No. 13 shows that a 105 ft lwl WarpDrive Lighter offers a slightly larger payload fractions than the longer-legged Freighters, by a factor of approximately 5% to 10%. As with Freighters, shorter Lighters would have the same payload fractions, but within their slower speed domains.

Figure No. 13 - Payload Fraction with Fuel for 250 nm 105' lwl (125' oa) WarpDrive Lighter

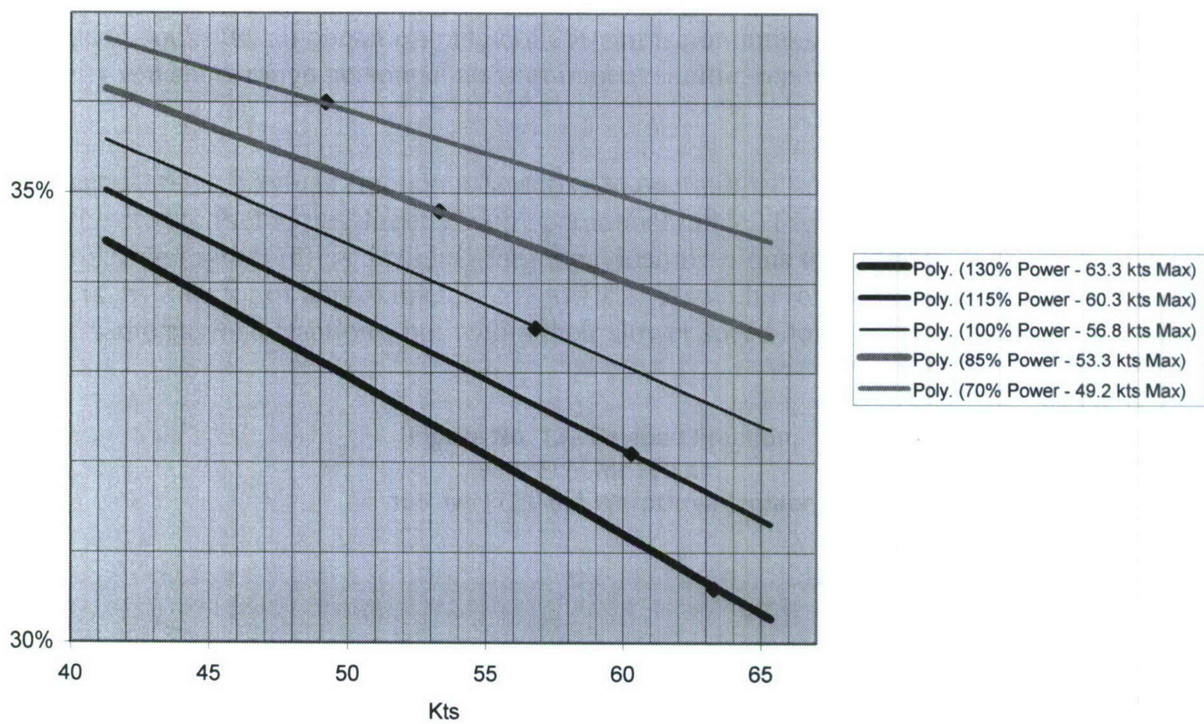
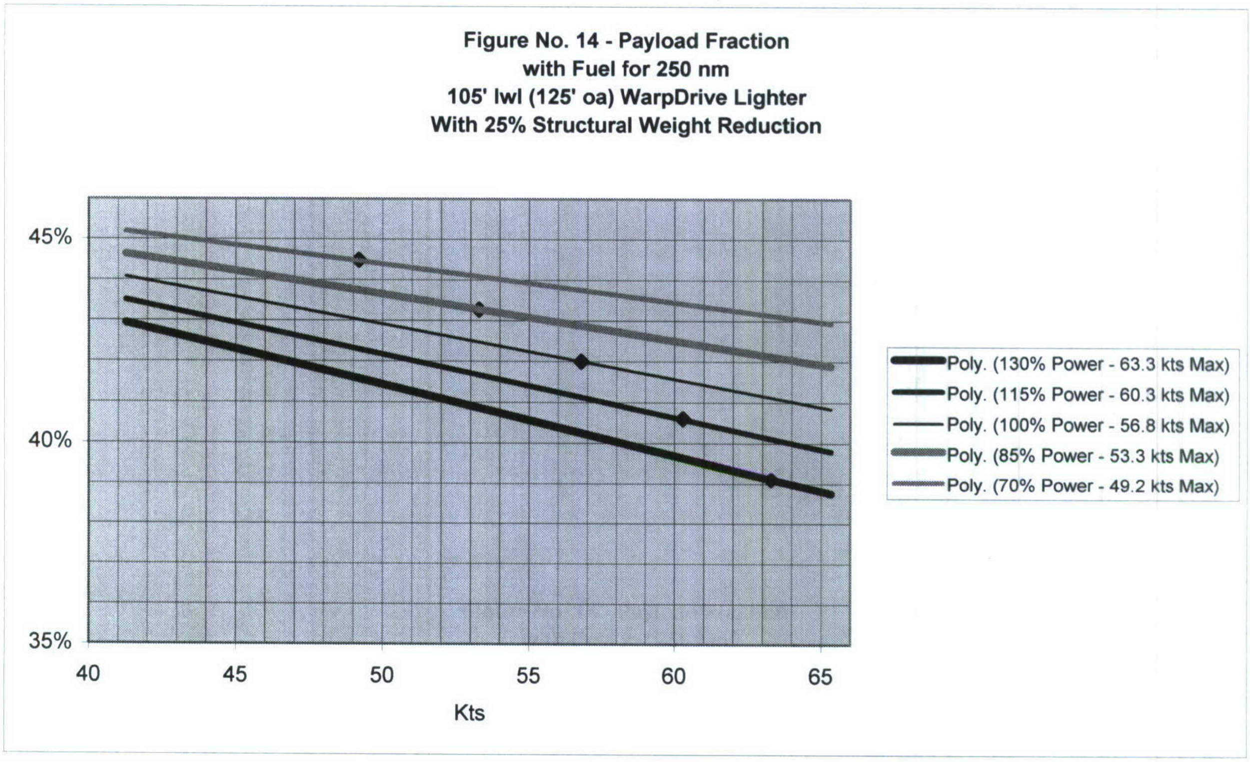


Figure No. 14 shows that the same Lighter with light-weight structure is projected to have an exceptional payload fraction of from about 39% to 45%, depending upon speed and power plant option.



The projected fuel cost per LT of payload per nm, at an assumed diesel price of $3.65 per gallon, for 63 and 105 ft lwl Lighters is shown in Figures Nos. 15 and 16. Again, substantially lower fuel costs could be obtained with light-weight structural composites.

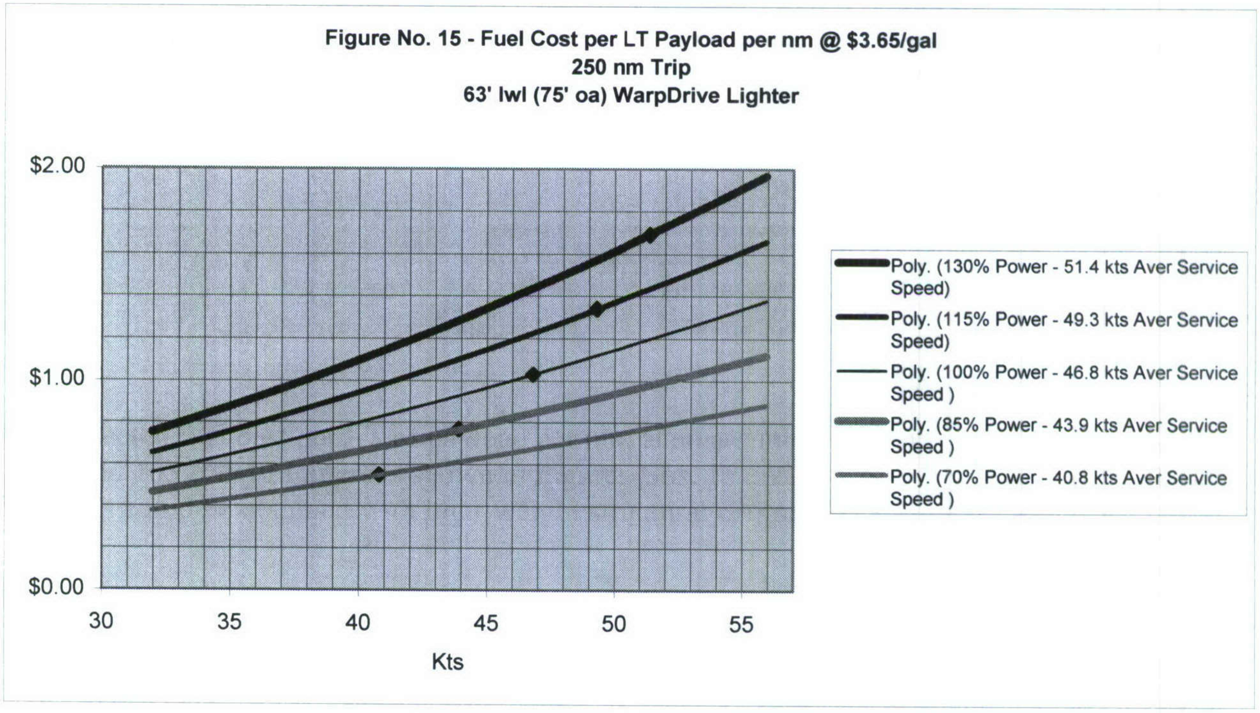
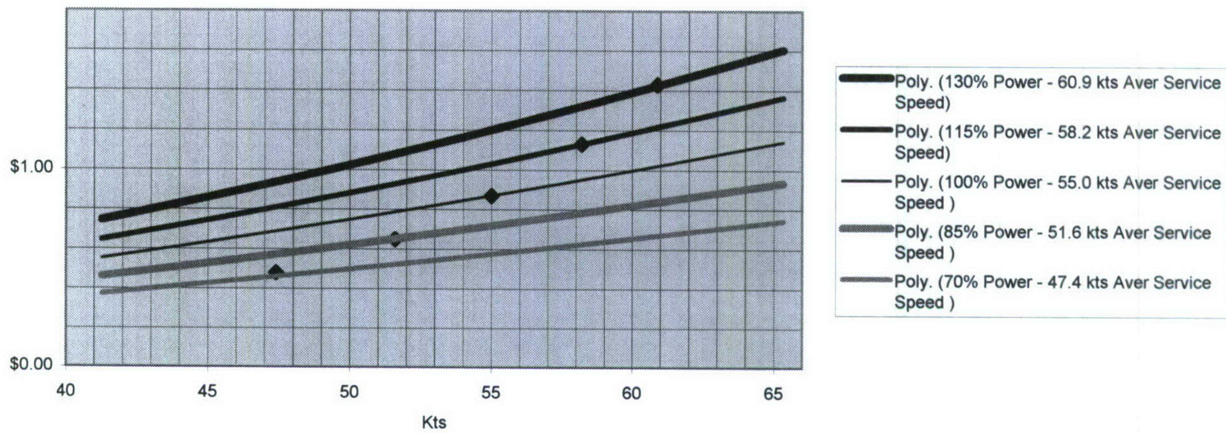


Figure No. 16 - Fuel Cost per LT Payload per nm @ $3.65/gal
250 nm Trip
105' lwl (125' oa) WarpDrive Lighter



The only U.S. Navy vessel with substantial payload fraction, other than Stiletto, that is claimed to make 40 kts at full load is the LCAC which is stated to be able to haul 60.0 LT at 40 kts for 200 nm. The LCAC is reported to have a standard displacement (i.e., full load displacement less fuel load) of 102.8 LT. Table No. 3 compares the LCAC with an 84 ft lwl (100 ft oa) WarpDrive Lighter with a 70% power plant installation that has a very similar 102.1 LT standard displacement. This size WarpDrive Lighter has a full load displacement of 178.6 LT, or 9.6 LT more than the LCAC. At full load, the WarpDrive craft carries only 2/3 the weight of fuel as the LCAC. Consequently, the WarpDrive craft enjoys a 20% advantage in payload capacity. Perhaps most startlingly, because of this payload advantage, and because of the low density of kerosene (that is assumed to be the fuel for the LCAC gas turbines), the tankage (in gallons) of kerosene is much higher than the WarpDrive draft's diesel fuel tankage, which, despite the lower cost per gallon of kerosene, results in the LCAC costing four times as much to operate fuel-wise as the WarpDrive craft per payload LT per nm.

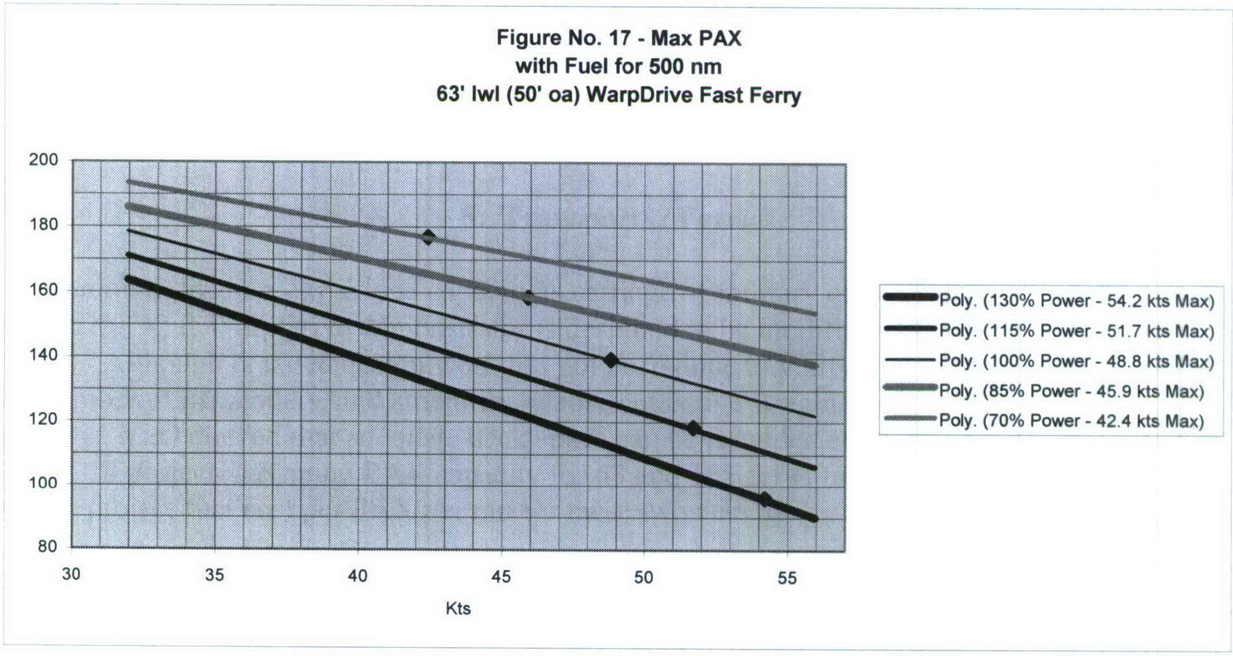
Table No. 3 - WarpDrive Lighter vs LCAC

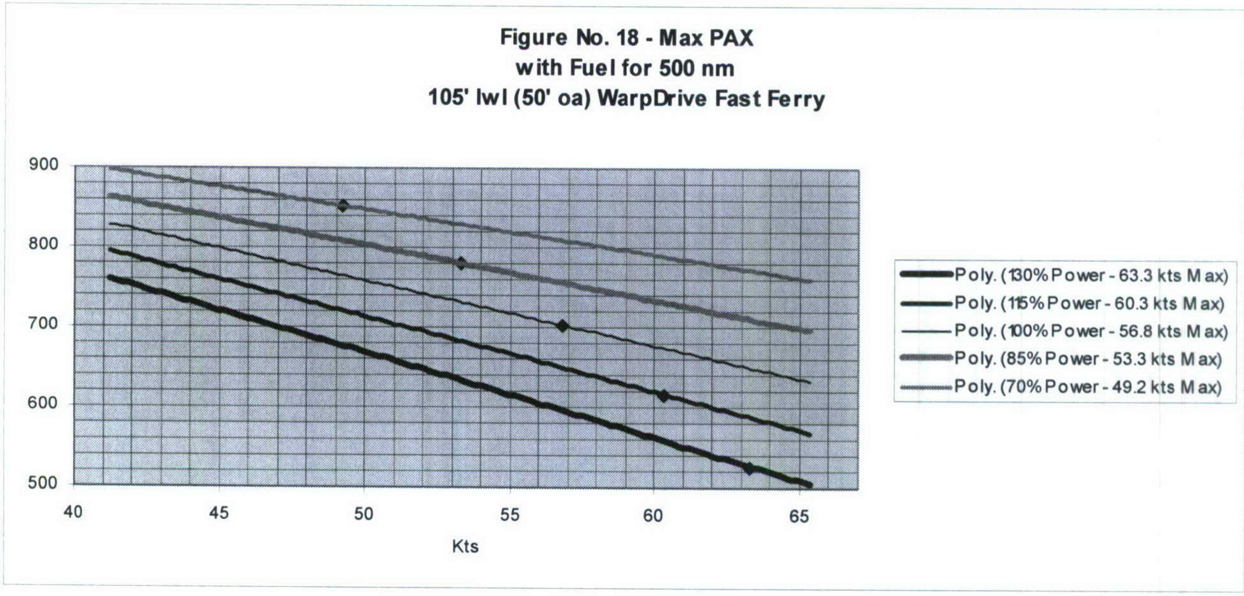
	LCAC	**WarpDrive**
Displacement (LTs):		
Standard Displacement	102.8	102.1
Fueled	109.0	106.3
Full Load	169.0	178.6
Full Load Payload (LTs):	60.0	72.3
Fuel for 200 nm full load @ 40 kts (LT):	6.2	4.2
Fuel Cost (@ $2.25/ gal kerosene; $3.65/gal diesel):		
Tankage for 200 nm	$16,047	$4,803
Per LT payload per nm	$1.34	$0.33
Full Load Range (nm) @ 40 kts:	200	200
Max Speed (kts):	54	57.7

LCAC data from USNI's "Guide to US Fleets" and "Combat Fleets of the World".

5. Transports / Ferries

A common utilization of payload capacity is carriage of military or civilian passengers. As noted earlier, the 42 ft WarpDrive demonstrator is designed to be modifiable to carry 49 passengers (PAX). Although detailed design work has not been done to verify availability of deck space for the number of passengers, and amenities, whose collective weight can be carried by WarpDrive scaleups, it is believed that adequate deck space can be provided at all examined scales. Figures 13 and 14 project maximum PAX capacity for 63 and 105 ft lwl fast ferries, and Figures Nos. 17 and 18 project fuel cost per PAX per nm for these two vessels.





Figures Nos. 19 and 20 chart fuel cost per PAX per nm for 63 and 105 ft lwl fast ferries.

Figure No. 17 - Fuel Cost per PAX per nm @ $3.65/gal
500 nm Trip
63' lwl (75' oa) WarpDrive Fast Ferry

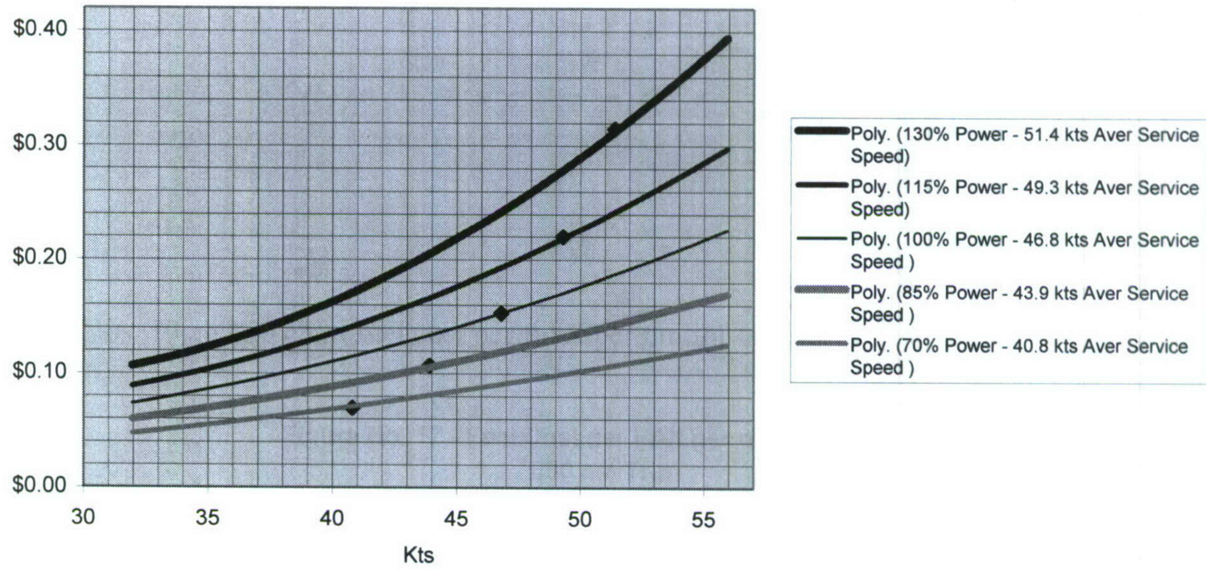


Figure No. 18 - Fuel Cost per PAX per nm @ $3.65/gal
500 nm Trip
105' lwl (125' oa) WarpDrive Fast Ferry